Disjunctures of Practice and the Problems of Collapse

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Abstract This chapter asks what insights long-term historical information from before the Great Acceleration and Anthropocene might offer to policy and practice in the twenty-first century. Conventional sustainability research usually focuses on shallower time horizons that could miss insightful environmental and social processes evolving over centuries to millennia. Although we push for increased engagement with historical researchers, parallels between pre-modern and contemporary environmental and societal challenges need to be treated with caution. So-called cases of societal collapse—often associated with environmental calamities—provide limited or at best flawed parallels with challenges faced today. The pitfalls of reductionism and determinism that often attend collapse discourse account for social agency and complexity in incomplete and unconvincing ways. Instead, we argue that historical evidence should serve as context to environmental problems faced today, as antecedents of the accelerated environmental change of later modernity rather than as direct analogies. Historical antecedents can be understood, to an extent, as previous

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experiments against which to test and improve theory or to structure possibilistic scenarios that help anticipate unexpected social and environmental challenges. In concluding, we suggest that researcher in historical sciences and the humanities require resources, space and incentives to explore sticky questions of uncertainty, risk, and vulnerability to environmental change together with global change researchers, policymakers, and environmental practitioners.

Keywords Anthropocene · Collapse · Environmental Humanities · Global Change · Environmental History · Archaeology

Introduction

Archaeology and history have long research traditions focusing on human–environment interaction (Trigger 2006). Environmental history and environmental archaeology research traditions, in particular, cover a substantial body of material evidence, reconstructing how humans perceived and changed their environments, how different cultures utilized natural resources, and how societies responded to short and long-term environmental change (Haldon et al. 2018; Riede 2017; Kintigh et al. 2014a, b). This latter focus has received sustained attention since the second half of the twentieth century and has been dominated by cases of so-called collapse (Tainter 1988). However, as Butzer (2012: 3632) explains, "the concept has intuitive appeal but ambiguous meaning" that draws attention to historical disciplines, but without sufficient clarification of relevance (Richer et al. 2019) or validity under closer scrutiny. This chapter addresses the pervasiveness of collapse and resilience concepts with the aim of reconsidering how historical data, case studies and 'lessons from the past' may be applicable in environmental science, as well as in various policy and governance (e.g. planning and emergency response) contexts. If we are indeed now living in a no-analog age, then some of the most significant challenges for historical disciplines today include identifying, unpacking and demonstrating the relevance of pre-modern social and environmental cases not only to present-day vulnerabilities, but also to scenario-building efforts intended to better prepare our societies for potential social-ecological crises and risks in the future.

Among other questions, this chapter asks what insights and information from before the Great Acceleration and the Anthropocene (as most widely defined) may hold for the wicked and messy environmental challenges facing twenty-first century globalized society. In turn, we consider the insights and richness that deep-time perspectives can offer to global change research, particularly now in the first years of the United Nation's Decade of Action to deliver the Sustainable Development Goals as the international science community and intergovernmental bodies attempt to address, with increasing urgency, climate change, biodiversity loss, wealth disparity, unsustainable consumption and resource usage as well as a great many other global challenges (UN SDG 2021). These high-level actors, internationally and nationally, have begun to be more active and vocal in efforts to engage scientific domains such

as qualitative social sciences and the humanities, as well as indigenous knowledge communities, in the very processes of knowledge production, scientific assessment and policy advisement that have effectively excluded them for the past half century (Castree et al. 2014). The Club of Rome's report *The Limits to Growth* (Meadows et al. 1972) helped to consolidate the environmental turn that had already begun as a grass-roots cultural and political preoccupation in the 1960s into an ever more coherent policy agenda of national and international prominence from the 1970s and 1980s onward (Blewitt 2018). However, the role of humanities and qualitative social sciences in large-scale efforts to assess relevant scientific knowledge for the purposes of policy planning on questions of environment, climate, conservation and sustainability has until the past few years tended to regard these knowledge domains (historical studies and critically examined data sources of the past in particular), as *othered* bedfellows so strange they have essentially had no place in the bed, reminiscent of the famous opening line of L.P Hartley's novel *The Go-Between*: "The past is a foreign country; they do things differently there" (1953).

There are some very notable signs recently that the situation has changed and that active collaboration is genuinely being encouraged between mainstays of the global change agenda, such as geosphere and biosphere research communities, and humanities disciplines, including historical studies, anthropological/archaeological disciplines, cultural heritage, arts and philosophy. These include: (1) UNESCO's formalization in spring 2021 of the humanities-led BRIDGES Coalition as the Sustainability Science arm of its international science programme Management of Social Transformations; (2) the first ever UNESCO-ICOMOS-IPCC International Co-Sponsored Meeting on Culture, Heritage, and Climate Change and in December 2021 and publication of three white papers scoping the crucial intersection of heritage and climate in early 2022 (UNESCO 2020a, b; ICOMOS 2019).

While these developments are certainly welcome and long overdue, recent high-level international initiatives promoting the value of integrated humanities, social sciences, and natural sciences research for sustainability, including co-production of knowledge and solutions-orientated action on global challenges with diverse (non-academic) societal partners, carries its own risks tied to no small degree with the very ambitions on which many of these scientific, epistemic and social innovations rest (Castree 2014, 2016; Jackson et al. 2018). Enhanced expectations of the strategic benefits that historical case studies and data can provide to policymakers, in tandem with previously siloed wisdom from non-academic communities (e.g. knowledgeable local citizen scientists partnering with scholars and scientists, inhabitants of threatened social and environmental systems, including indigenous communities), can run the risk of producing shallow or scientifically questionable results if scientific integrity and quality take a back seat to shorter term political or social agendas, however meaningful and justifiable these priorities may be on their own or in a wider societal context. This is the note of caution on which we conclude, together with a series of questions proposed for further investigation.

Historical Experiments: Primacy, Principle and Practice

What role can past cases of social-ecological system disturbance play in helping scientists, policymakers and environmental managers address present and future vulnerabilities facing societies in the twenty-first century? Why and how societal crises typically develop, as well as what shapes their generalized outcomes, are questions of central interest not only to the risk and crisis research community but to planning, governance and response agencies. These are questions where historical research disciplines, it would stand to reason, should be in a strong position to contribute knowledge and useful case studies capable of having real world impact. How well does such an expectation hold up? Can case studies of particular past societies that underwent extreme exogenous or endogenous stress demonstrate whether certain communities or socioeconomic structures are more amenable to change without losing vital system capacities or integrity? Efforts to address such questions may understandably tempt us to think in rather reductive values of success or failure. Such logic, along with the master narratives that undergird it, have exerted a powerful hold on the popular imagination in recent decades (Diamond 2005; see Middleton 2017) and have even influenced policy and governance agendas to some degree (see IPCC AR5, Chap. 16, 2014).

Why are some past societies considered as more successful, having adapted to major human or natural disturbances, while others have become the historical poster children of societal collapse and failure? In the clarity of hindsight, the causes of what has been described as societal collapse in many of these narratives can appear predestined. In some cases, unsustainable resource use can expose societies to long-term deprivation in what has been termed world systems theory—the transition of societies from core, hegemonic to more marginal, peripheral political economies (Wallerstein 2004)—or exacerbated existing inequalities potentially leading to what often gets called 'collapse' (Tainter 1988; Diamond 2005; Kohler and Smith 2018). For other societies, exposure to acute shocks, such as extreme weather events (e.g., flooding, drought, extreme heat or frost), natural hazards (e.g., volcanic eruptions, earthquakes, tsunamis) or warfare, can possibly trigger violent shifts in operational and governance capacities at their prior levels of complexity. Such shifts in complexity—or threshold crossing events—have been conceptualized using a range of theoretical frameworks and have occupied significant debate in archaeology and history, particularly in the last 15 years (Tainter 2003; McAnany and Yoffee 2010). How to usefully characterize sudden disruptions or more chronic stress and their respective effects on past societies have been central to the discourses of *collapse*, and more recently *resilience*, including discussions of what these concepts specifically mean and entail, and if they can indeed help us to understand the dynamics of long-term social and environmental change (Aimers 2007; Middleton 2012, 2017; Jackson et al. 2017). Just what such system disruptions may be able to tell us about challenges associated with future environmental change, even the prospect of social-ecological system collapse, are questions of another kind and order altogether. However, in numerous sectors of

political and social debate, in technocratic interventions focused on innovation in the science-policy interface and indeed even within some nascent fields such as sustainability science, earnest efforts are underway to plan for mitigation of the risks our societies could face if pathway dependencies or system shocks contribute to future structural or functional changes in societies and environments from which these systems are unable to recover (Dow et al. 2013; Wise et al. 2014). Discussions and efforts unfolding in each of these sectors give meaningful space to rational consideration of how incentive structures underpinning human behavior, among other things, can be altered to avoid disastrous worst-case outcomes within such systems (O'Brien 2018).

Anticipating future hazards is a significant challenge that is both compounded and undermined by environmental complexity, technological innovation and the interaction of social systems with and within these systems (Bostrom and Cirkovic 2008). Popper (1956) termed this difficulty *The Poverty of Historicism*: the complexity of interacting natural and social systems making historical prediction intractable. From the perspective of risk science, this is due to two critical deficiencies. First, we cannot know the full range of future hazards that societies may face, nor characterize the extent to which they may yield harm (Hochrainer-Stigler et al. 2020). Poorly identified or poorly characterized hazards can leave societies open to surprise, making it difficult for stakeholders to adequately respond to threats as they arise, and for societies more broadly to understand how best to act and overcome associated disruptions (IRGC 2018; Hynes et al. 2022). One example of hazard uncertainty is captured in November's (2008) characterisation of the spatiality of risk, where new social configurations create ill-defined 'grey areas' for risk management. Attention has been drawn to the Geneva fire department's broadening of the traditional fire risks from poorly maintained apartments to incorporate risks on industrial estates that have been repurposed for residential and nightlife but may also include hazardous chemicals and machinery (November 2008). Second, even if we may have some knowledge of the hazards we could face in a certain area, there is a near infinite number of societal vulnerabilities that can influence or impact these hazards. Societal systems, from infrastructure to the environment, from commerce to governance and culture, involve a wide range of nested dependencies that, if disrupted, can generate sudden, cascading disruptions, breakdown or even failure (Hoffman and Oliver-Smith 2001). Even if we were to harden one potential vulnerability (e.g., safeguarding public health through agricultural sustainability), other unexpected exposure points remain (e.g., the sudden arrival of a deadly human pathogen). Moreover, conversation in the 'risk and vulnerability' research community emphasizes the cultural construction of disasters, proposing that societies generally tend not to be truly prepared or spared from the extreme effects of system disruptions, but merely manage shocks and longer-term stress on the system by distributing the risks internally to the most socially vulnerable groups and the most redundant structures and functions (see, e.g. Oliver-Smith and Hoffman eds. 2020). This is a view consistent with environmental humanities scholar Rob Nixon's concept of *slow violence* (Nixon 2011) and calls to mind Joseph Tainter's oft-noted observation: "Some people and some ecosystems benefit from sustainability efforts, while others don't. When confronted with the term

"sustainability," therefore, one should always ask: Sustain what, for whom, for how long, and at what cost?" (Tainter 2003, 214–15).

From an historical perspective, path dependency and lock-in can have significant ramifications for social, political and technological transformations towards sustainable and resilient societies (Wise et al. 2014; Adamson et al. 2018; Jackson et al. 2018; O'Brien 2018). System path dependence, especially in environmental policy, can reinforce a tendency to favor status quo operations, making it difficult for societies to anticipate risk and build capacity (Samuelson and Zeckhauser 1988; Yudkowsky 2008; Riede and Jackson 2020). An example of this is the identification of socio-technical lock-in, such as car culture, that undermines the wider transition to public transport and cycling in urban environments (Urry 2007; Geels 2012). Lacking a catalyzing incentive to change (or a disincentive to move away from existing behaviors, e.g., unsustainable resource consumption), societies can become locked into path dependencies that leave them increasingly vulnerable to crisis. A prominent example of such pathways can be seen in the Representative Concentration Pathway projections of IPCC AR5 (2014), which plot a range of possible emissions trajectories that map onto climate risk projections in what have come to be known as the 'burning embers' diagrams.[1] Path dependent behaviors have become ossified in common assumptions about economic logical and rational choice. Such assumptions of *Homo economicus* fail to take account of irrational practices that damage public health and fail to take anticipatory action to address environmental damage (Dietz et al. 2003; Thaler and Sunstein 2008; Palma-Oliveira et al. 2018). This may be associated with insufficient information to inform choices or social norms that create path dependent behaviors—with notable examples including dietary choices due to lack of choice or information, personal hygiene such as washing hands, and driving rather than taking public transport—all of which are informed by choice of architecture (i.e., infrastructure, social context) (Thaler and Sunstein 2008). Adapting from one paradigm to another often requires a forceful driver that, while reorienting societal and environmental system properties, can also lead to highly unfavorable outcomes (Allen et al. 2019). Even when extreme systemic change generates growth and normatively preferable long-term outcomes, the lived experience of those in the time of crisis may be violent, unjust, chaotic and prone to deprivation.

Policymakers and scientists need insight not only to identify the characteristics that promote societal resilience to disruption, but also realistic approaches to how such resilience might be generated without the risk of sweeping societal harm. Historical cases, because they may be viewable from a distance as "completed experiments of the past" (Speilmann et al. 2016; Nelson et al. 2017), provide narratives and insight into both needs, yet lessons from historical scholarship only reach decision makers with considerable difficulty and historical expertise may be ignored or mis-applied. In the post WW2 period, the "lessons of history" for many policy makers were largely restricted to the perceived lessons of the Munich appeasement, leading directly to

[1] As Mahony and Hulme (2012) explain, the "burning embers" diagrams that have featured in the IPCC Assessment Reports have become prominent visualisations of abstract conceptualizations of future risk.

prolonged and deadly intervention in conflicts in Vietnam, Laos, and Cambodia that produced long-term human and ecological damage that continue to the present (Hess 1994; Hendrickson and McMaster 1997; Khong and Yuen 1990). Pathway dependency and failure to apply appropriate locally scaled historical perspectives have had similarly disastrous outcomes for US, Soviet, and other outside military and nation-building efforts in Afghanistan where Afghan and Central Asian long-term history and the political dynamics of kin-based society regulated by feud were ignored and inappropriate social, economic, and military models were initially employed and never seriously reconsidered over decades of conflict (Loyn 2009; Waldman 2013). Neither Western nor Soviet leadership applied the locally scaled "lessons of history" of prior social and economic structures in both South-East and Central Asia that promoted long-term resilience in the face of both local factional and ethnic conflict and resistance to external hegemonic threats (Mongol, Chinese, French, British, Russian). The input of historians and social scientists aware of the actual local historical backgrounds, the likely future range of social strategies of resilience and repeating local patterns of social durability or fragility were ignored or undervalued by a succession of policymakers applying inappropriate historical lessons.

Theory as Tool: Complex Adaptive Systems

Better connecting appropriate historical cases with other data and the analytical tools of complex systems theory or other scenario exercises (Rounsevell and Metzger 2010) could help to bridge such gaps. To understand change in the past, the traditional approach is to establish a temporally ordered chain of events, termed causation, which allows generalization about a behavior. Causation is a dependent relationship among events/properties/variables. If we are to learn from the past, the establishment of causation is both fundamental—in that a chronology of events is necessary—and problematic, because the past, like the present, is the sum of many events, properties, and variables that operate at various temporal and spatial scales and have relevant properties (e.g., slow/fast, change in rate of change). The adaptive cycle common to resilience serves more often as a model or metaphor for change over time rather than a road map for complex interrelations.

Complex adaptive systems (CAS) can carry research into deep time and offer a more nuanced and practical interpretation of the past. CAS offer several ways to analyze and incorporate time into historical analysis: initial conditions, path dependency, a tendency to undergo irreversible processes (thus creating system history). Complex systems (such as the human–environment relation) are comprised of both linear (predictable) and non-linear (emergent) properties. This fundamental dynamism makes CAS the very essence of change over time (Sinclair et al. 2018). The establishment of this more robust form of causation requires a meta-theoretical approach that considers the properties of dynamic systems (Allana and Clark 2018). Research in this arena focuses on how the entire system operates and how its design and operation affect risk (Webster 2005). A tight chronology of events before the fact

is a first step in the study of dramatic change and remains indispensable. However, many ways of knowing about the past (e.g., documents, environmental data, archaeological materials, individual and collective experience) add to the diversity of information, offer cross-checks to its interpretation, and contribute to a more holistic reading of key factors that shaped decisions.Interactions can be influenced in several ways, including path dependency, feedback, and memory. Path dependency means that past events amplify through positive feedback to strongly affect interactions today. For instance, the loss of Finland to Russia in the Swedish-Russian war of 1808−9 led to border closures, which continue to influence the development of reindeer husbandry in Sweden (Moen and Keskitalo 2010). The tendency of decision makers to follow and amend earlier decisions is powerful, minimizing costs and disruption and adhering to tradition. Feedbacks are chains of events that influence themselves, either positively or negatively. A classic example of a positive feedback is that the higher temperatures of climate change melt ice and snow at high latitudes, changing the albedo (the reflectivity of the surface) and trapping more heat, which in turn increases temperatures, and melts more snow. Memory and short system history may also affect interactions. One example is the common use of baselines in fisheries management to assess the wellbeing of preferred species, using recent data and individual experience, thus missing the tell-tale signs of earlier mismanagement (Engelhard et al. 2015). All these modifications have strong effects on dynamic systems.

Diversity, Flexibility and Durability: An Alternative Nomenclature with Alternative Implications

The concept of *durability* has been introduced (Murphy and Crumley 2021) in contrast to the more familiar terms of resilience and sustainability. The term *resilience* is often used simply as the ability to withstand a shock without a fundamental change of functions, whereas forms that permit reorganization at diverse scales and contexts of time and space, while others remain unchanged, can be examined more usefully, and perhaps less opaquely, using the concept of durability. Most importantly, resilience does not offer a robust means for dealing with change over time.

The term *sustainability* also tends to fail the needs of different communities of practice because it often carries the connotation of 'able to be continued indefinitely' (e.g., an activity that does not acknowledge the inevitable reality of a resource's deterioration or depletion) and does not fit well with complex dynamic systems that endure diverse challenges. To apply lessons from the past to today's issues, we must keep in mind that most social systems—ancient and contemporary—have suffered the impacts of climate change, population fluctuations, resource depletion, pestilence, and greed.

Durability, in contrast, is the positive outcome of practices and strategies that were undertaken and refined over time as the context changed (Murphy and Crumley

2021). A durable system is the result of a long-term process that is characterized by continuous development, accumulation of knowledge, and incremental experimentation and observation. It includes how societies regenerated after episodes of 'collapse' or managed the 'art of not collapsing'. By studying the trajectories of durable systems that we can investigate in the archaeological and historical record and in communities of practice, we can avoid some of this trial and error (Crumley 1994, 2007).

Working through case studies that span geographies, cultures, social systems, and time periods, we identify common threads that represent various levels of success in past efforts to cope with changing environmental conditions. These approaches often combine mitigation and adaptation activities undertaken in close collaboration with local and indigenous communities.

Durability does not, however, imply lasting forever. Durability introduces the idea that things will not last forever and must be maintained, while simultaneously advocating for investing in the right moves that will help these things last longer. The characteristics of management strategies that lead to durability are worth examining and establishing more fully. It is necessary to study further the effects of short-term decision making on long-term durability, including how decisions made by distant policymakers may ignore thoughtful strategies that provide the 'non-declining utility' (a common definition of sustainability) of key resources (e.g., soil, organic matter, fresh water) over relatively long timescales. Recent work has begun to detail which factors contribute to the building of durable systems and which introduce vulnerabilities over great time scales, from several centuries to millennia (Brewington et al. 2015, Hicks et al. 2016).

Two such factors are diversity and flexibility. For long-term societal survival, archaeological data and historical records show us that *diversity* is key. A recurring strategy found in durable systems includes the *flexibility* that diversity provides. These reinforce one another: while diversity (of resources, strategies, and perspectives) is the basis for wider choices, flexibility is the ability to alter management and governance to better fit the situation. Biocultural diversity is the basis for flexible social, political, economic, and other strategies. Diverse and flexible strategies within a social-ecological system that has some slack—where each key variable need not be 'just right' for the system to function—offer risk management options that provide vital latitude in the face of external or internal changes (Dugmore et al. 2013).

Many of the long-lasting examples in the archaeological and historical record involve political systems that were dramatically transformed over time, but which overlay a social system that lasted millennia (Meyer and Crumley 2011). These underlying systems were diverse and flexible; they were also labor-intensive, and often imbued with a worldview that honored and protected key resources. They contrast dramatically with today's widespread clear-cutting, fossil-fuel dependency, high energy requirement, use of chemical fertilizers and pesticides, monoculture, and so on, to produce food (Hilding-Rydevik et al. 2018; Iuga et al. 2018). Past practices and management strategies are reservoirs of knowledge that provide viable options for today and can point to alternative strategies for the future.

Learning from Systems Under Stress: Antecedents and Anticipation

Modern societies are afflicted with a variety of stressors that may yield substantial and lasting harms if not ameliorated. The SARS-CoV-2 pandemic (hereafter COVID-19) contains an abundance of potential cases where we can see clearly divergent outcomes: nations/sectors of short-term or blunted impact, nations/sectors with extensive disruption yet rapid recovery, and nations/sectors with sustained and grievous losses in complexity. In some societies the economic, social, and environmental sectors, and their assets, have recovered quickly from disruption, while others lag well behind their pre-pandemic levels of functionality. The core variable informing system performance in this regard is often described as the systems' *resilience*, or system capacity to recover from and adapt to disruption (Hynes et al. 2020). Systemic resilience can be influenced by history, nature, and current culture, as evidenced by the very different outcomes of COVID-19 response in island states like Iceland and New Zealand with high levels of contemporary political cooperation (social capital) and investment in science education and deep historical memories of disastrous epidemics as part of the national historical narrative in comparison with nations experiencing depleted social capital and easy international and inter-regional travel when confronted by pandemic. In Iceland and New Zealand, the impacts of smallpox in the eighteenth and nineteenth centuries form part of school curricula while the story of the 1917–21 Spanish Flu was a specialist subject in the US until 2020 (e.g., Moxnes and Christopherson 2008; Flecknoe et al. 2018). It may be that resilience can be driven by accumulated social capital and the presence of an ocean "moat" in the recent pandemic examples of Iceland and New Zealand, but effective policy still needs the support of a fully and appropriately mobilized historical consciousness for policymakers.

The study of complex systems is a growing field of scholarship driven by a desire to understand how various societal, infrastructural, and economic interconnections collectively influence actions and outcomes (Urry 2003). Such systems thinking is usually driven by a desire to understand susceptibility to extreme events or shocks in modern complex societies increasingly reliant on interconnected digital systems to facilitate functionality (Walker and Salt 2012). Though this sort of scholarship may certainly be helpful in enabling societal resilience in the face of a variety of uncertain and complex disruptive events, its emphasis on exploring modern systems to the exclusion of the past ignores one promising avenue of inquiry—the ability to understand and explain why certain societies or institutions in the past survived and recovered from significant disruptions, and why others appear to have collapsed or declined into reduced forms for extended periods of time.

Systems theory and resilience are philosophies and analytical strategies that can help explain how internal system structure and characteristics (or "endogeneities") influence the capacity of systems to prevent, mitigate, and recover from external shocks and stresses of an extrasystemic nature (or "exogeneities"). Systemic threats are those understood to have consequences or outcomes that can reverberate

throughout various elements of society, such as an epidemic which has the capacity to disrupt local economies or governance procedures. States with rigid, inadaptive or brittle institutional, political, and economic systems may be more prone to lasting disruption or even collapse in the most extreme cases. Similarly, those with the capacity for recovery and adaptation in the face of a systemic exogenous shock may be far more likely to survive and even thrive in the aftermath of such disruptions.

The potential importance of historical cases and popularly perceived "lessons of history" in driving current understanding of societal challenges and emergencies cannot be understated. As the COVID-19 pandemic began to spread, everyone from senior policymakers to individual households searched for metaphors and lessons to mitigate possible harms and anticipate what might happen next. Lacking comparable cases from the recent past, experiences of the 1917–20 Spanish Flu pandemic a century before were initially ignored, and some lessons (extensive masking, moving classes outdoors, reducing crowding) were applied late and unevenly despite the clear historical record of the impact on local mortality in a much deadlier pandemic event. Failure to understand and act upon the practical historical lessons of the 1917–20 pandemic certainly exacerbated systemic losses from panic, fear, misunderstanding and ultimately self-destructive actions at national and smaller-scale community levels, as well as at the level of individual response.

Though it is impossible to predict all future hazards, an improved synergy from historical cases to present and future challenges can help to: (a) equip many with more nuanced understandings of how complex societal systems function under duress, recognizing the tradeoffs between optimizing short term efficiency and long-term durability and resilience (Hegmon 2017); and (b) provide some useful lessons and strategies—a so-called usable past—that can contribute to more normatively favorable outcomes (Cooper and Sheets 2012).

What Relevance Can History Have if We Are Living in a No-Analog Age?

The Anthropocene has been subject to intense discussion and debate in the environmental and social sciences and humanities for its implications for the nature of human social life and ecosystem processes (Chakrabarty 2009). It is most commonly defined as commencing in 1950, marked by a global radionuclide marker and the expansion of extractive industries, mass consumerism and population growth (Steffen et al. 2011, 2015) as well as rapidly escalating emissions of carbon dioxide into the earth's atmosphere owing to numerous interrelated developments, such as increased urbanization, industrial expansion and globalization of commerce. Other suggestions place the beginning of the Anthropocene in the eighteenth century, at the start of the industrial era (Steffen 2003) or, more controversially, 5–8 millennia BP (Ruddiman 2003, 2007). Ruddiman's (2013) early Anthropocene claim rests on the hypothesis that land-use change associated with the transition to agriculture and animal husbandry

was responsible for the stabilization of climate. But, as Erlandson and Braje (2013) write, the arbitrary date for the start of this epoch is less relevant than the antecedent factors that shaped it. Both archaeology and history provide evidence of the shaping of the human niche in the earth system and how humans have adapted to long-term climate variability (Smith and Zeder 2013). This contextual knowledge has a significant role to play in unravelling the complexity of human impacts on and entanglement within natural ecosystems (Boivin et al. 2016). This contextual knowledge is also important in understanding the efficacy of long-term adaptation to environmental change and how different scenarios may have played out when societies were faced with acute stress. However, context also helps to highlight the dilemma of commensurability of scales, tools, methods and data (both their availability and resolution) when we seek to compare cases and engage multiple disciplines across the spectrum of scientific domains.

The subject of 'relevance' in historical and archaeological research—including the associated discipline of palaeoecology—has received significant attention in recent years (Hudson et al. 2012; Richer et al. 2019). This is a corollary of a broader shift towards practical, impact-driven knowledge production in what has come to be known as 'Mode 2' science (Barry and Born 2013; Nowotny et al. 2013). The shift from 'Mode 1' to 'Mode 2' knowledge production has redirected the emphasis from knowledge driven by theory and academic audiences (Mode 1 knowledge) to a wider audience in civil society, policy and practice—so-called transdisciplinary and co-produced knowledges (Mode 2 knowledge) (Collins and Evans 2002). For archaeologists, this development has increasingly favored efforts to draw civil society into knowledge production through community archaeology (Dawson et al. 2017; Stump and Richer 2017), citizen science (Smith 2014; Dawson 2015) and museum exhibitions (Jackson et al. 2017; Riede 2017), and has prompted debate and discussion on the role that archaeology can and should play in addressing environmental and social problems (Dawdy 2009; Riede et al. 2016; Rockman and Hritz 2020). The same can be said of other historical studies disciplines generally, even if the methodological realities of data retrieval and culture of scholarship in long established or traditional approaches to historical research have tended on the whole to make archival documentary research more of an individual and intradisciplinary pursuit than has typically been the case in field-based archaeological and paleoenvironmental research, which have long favored interdisciplinary methodologies and transdisciplinary forms of collaboration and community cooperation. There have been calls for some time to consider the advantages of team-based interdisciplinary and transdisciplinary approaches in particular as a viable model for conducting integrated historical research, and these calls have increased in recent years especially within projects and approaches such as historical ecology, integrated environmental humanities and cross-field intrahistory study (historical-archaeological and paleoenvironmental consilience research) (Crumley 2007; Haldon et al. 2018; Hartman et al. 2017; Hartman 2015, 2016, 2020; Izdebski et al. 2016).

In some respects, the question of what relevance archaeology and history have is fairly straightforward if not muddied by the popularity of collapse discourse in

academia and civil society (see Jackson et al., *this issue*). The most obvious relevance of these disciplines, as well as those closely adjacent (e.g. historical geography, historical anthropology, historical climatology, even paleoecology and paleoclimatology), is their combined ability to help reveal the story of human history and the co-evolution of society and environment (Haider et al. 2021). Popular non-fiction literature, such as Jared Diamond's *Guns, Germs and Steel* (1997) and *Collapse* (2005) and Yuval Noah Harari's *Sapiens* (2011) and *Homo Deus* (2015), provide sweeping narratives of the rise of modern societies and the resulting impacts on environments past, present and future. Without intense archaeological and historical research, these highly influential texts would not be possible, but it should also be recognized that these texts are also widely contested (see for example McAnany and Yoffee 2010) and apply particular frameworks (e.g., determinism, reductionism) that articulate history in particular configurations of cause and effect.

But if we are to learn from history, how one reads the past should be considered. *Which* lessons of history become embedded in popular culture and become privileged in scenario building for current and future policy making have critical importance. If the only memory of conflict avoidance is Munich and Appeasement, then the pathway to frequent military interventions and massive investment in standing military deterrence on hair trigger readiness becomes immediately deepened and widened. A wider reading of historical examples might flag up the recurring problems of past states over-investment in militaries increasingly unsuited to their actual missions leading ultimately to state instability and painful hegemonic transition.

Archaeological and historical records can be broadly divided into two categories of relevance: discrete and continuous. Discrete information includes examples of so-called completed experiments of the past, where societies have a discontinuity with the present. Abandoned settlement or societies that came to an unrecorded end fit within this category and have often been examined for retrospective evidence of social vulnerability, social-ecological resilience and adaptative capacity and flexibility (Diamond and Robinson 2010; Butzer and Enfield 2012; Speilmann et al. 2016). Continuous information, by contrast, has a continuity with contemporary environmental and social problems (Sachs 2020). Mass extinction, land-use change, species domestication and the evolution of societies and technological innovations can all be understood through a retroactive analysis of human–environment interaction (Boivin et al. 2016) that remains ongoing. Example of these continuous data are the vast archives of animal bones and historical records of commercial fishing in the North Atlantic since ~AD 1000 (Kwok 2017; Barrett 2018). Such records provide evidence of the scale of fishing, the average catch size and the spatial distribution of fish over the last millennium, improving our understanding of human impacts on marine ecosystems at the local and regional scale and offering a revised baseline for pristine marine ecosystems (Hambrecht et al. 2018; Hilding-Rydevik et al. 2018).

Though underutilized, archaeological data that have a continuity with contemporary environmental impacts has a clear relevance for policy and practice (Cooper and Sheets 2012). Legislation on marine protected areas and broader conservation and resource-use practices can benefit significantly from a deeper understanding of the long-term impacts of human activities on ecosystem structure (Dunne et al. 2016).

But if discrete archaeological and historical records are to have a relevance in policy and practice, the lessons need to be interpreted carefully and translated with a clear acknowledgement of the opportunities and limitations of such datasets (Table 1). A consistent criticism of Diamond's historical narrative has been his lack of training in archaeology and history, but for a clear recognition of relevance to be grasped, historians and archaeologists must provide a clear exposition of opportunities and limitations of using such records (d'Alpoim Guedes et al. 2016). This can permit the location of usable archaeological information that is relevant to policy priorities (see Stump 2013), *usable knowledge.*

However, realizing this ambition way well depend on stronger concerted efforts among relevant scholarly communities to align historical studies, in the broadest and most usefully inclusive sense, with open science ambitions. This could be done, for example, by investing in expanded and robust cyber infrastructure enabling management and sharing of data more effectively across disciplinary communities without counter-productive contextual knowledge losses (i.e., with glosses and critical apparatuses that could help to translate data with greater nuance for use and distillation across scientific and scholarly communities). Such efforts would depend on building and enhancing research infrastructures, and targeting funding priorities that could enable them, that almost by definition would need to address wider scientific domains extending far beyond the needs of individual subjects. Such a vision of research design might well involve working backward from identification of present or future societal challenges to be addressed through integrated/consilient research on comparable challenges faced by societies in the past, and then identifying the knowledge needs to be facilitated in order to address those challenges through a more successful integration of data and methods than is generally observed today across distinct scientific/scholarly disciplinary communities. Such open science investments can also have further benefits by improving the science/policy interface.

What Deep Time Perspectives Can Offer to Contemporary Debates

Natural experiments are used increasingly in historical disciplines to formalize comparison because it is often not possible, for practical or ethical reasons, to conduct controlled laboratory-based experiments (Dunning 2008, 2012). In archaeology, this method has been used to examine, among other things, variation in artefacts styles to assess the linkage between technological change and environmental variables (Riede 2006, 2014), to examine the role of humans in the deforestation of Pacific islands (Rolett and Diamond 2004), and to examine patterns of subsistence, settlement and exchange using computation models (Kohler et al. 2012). Advances in computational modelling and data resolution in particular have improved our ability to link changes in human societies with environmental change (d'Alpoim Guedes et al. 2016). For example, such models have been used to examine the effects of climate change on

Table 1 Summary of the pros and cons of historical and archaeological studies with lessons of climate change impacts and adaptation

Table 1	Climate change adaptation studies of the past	
	Pros	Cons
Record length and resolution	Deep-time perspectives provide an extensive longitudinal analysis of human populations prior to, throughout and in the aftermath of climate perturbation, natural hazard events and other broader socio-political and economic stressors (Kintigh et al. 2014a, b; Riede 2014b; Butzer 2012)	Data resolution is limited to material remains, written records, and environmental proxies as evidence of human activities. Evidence may be incomplete, lack precision or be subject to bias given the methods, interpretation, and varied preservation of the record (Ogilvie 2010)
Multiple sites, cultures and rates of change	Deep-time records provide evidence of human responses (positive and negative) to the differential impacts of climate change. Multiple sites across space and between different cultures provide evidence of different strategies adopted to adapt to changing environmental, economic and political conditions (Nelson et al. 2006; Spielmann et al. 2016)	Selective human sampling of the environment plus differences in rates of preservation across archaeological sites can lead to an inconsistent and partial record across space and through time (Dawson 2015)
Distributed settlement networks and regional-scale environmental change	Distributed observational networks of the past offer new ways of combining local records of human activities in the past. Combining accurate datasets across entire regions provides a multidimensional long-term record of human adaptation to climate change (Nelson et al. 2016; Dugmore et al. 2013)	Societies of the past have inherent differences to societies in the twenty-first century. Revolutions in science, automobility, economic development and health distinguish modern societies and cultures from the past (Butzer 2012)
Analog and Analogy	The archaeological record offers a 'completed experiment' of the impacts on and responses of human populations to climate change (Dugmore et al. 2013)	The absolute size of population, settlement, economic networks, migration and infrastructure in the twenty-first century is without historical parallel (Butzer 2012)
	Processes and responses hold similar characteristics in contemporary and past societies. Equality, sharing and traditional forms of knowledge are similar processes in modern and pre-modern societies (Kintigh et al. 2014b)	Anthropogenic climate change is having effects on the rate and magnitude of global change on a scale never witnessed by human societies, though processes operating at the local scale are, in some cases, similar (Boivin et al. 2016)

maize cultivation and turkey raising in the prehispanic Pueblo societies of the US Southwest (Kohler et al. 2012; Bocinsky and Kohler 2014). Biocultural changes and human-environmental impacts have also undergone extensive analysis, comparing environmental variables with resource accessibility as a way of assessing societal resilience (Hegmon 2017; Spielmann et al. 2016; Rolett and Diamond 2004).

Studying social and environmental change from a deep time perspective offers useful context scales (from multigenerational to millennial-scale) to understand the origins of modern societal problems (Redman 2005; Marks 2015; Burke 2015). Kohler (2012) stresses this point to emphasize the importance of historicity to social evolution and response to social and environmental hazards. This requires consideration of the impacts that social and environmental phenomena have on the resilience of societies to hazards in the long term (Kohler 2012). For example, the investment in canal irrigation systems by the Hohokam in the US Southwest was successful over a multi-century timescale of sustaining farming, increasing settlement concentration, supporting investment in public architecture, and evolving hierarchical modes of governance (Nelson et al. 2012, 2016). Irrigation systems allowed settlements to manage short-term variations in precipitation, but this also enhanced reliance on the socio-economic systems supported by irrigation. As environmental conditions deteriorated from the late-14 and fifteenth centuries, the irrigation system was damaged by unanticipated flooding and was subsequently unable to manage extensive drought. The investment in communal infrastructures enhanced path dependency, making it difficult to invest in alternative resources (Nelson et al. 2012). By contrast, the Mimbres settlement, also of the US Southwest, shows no evidence of pronounced hierarchy and little investment in public infrastructure, and it developed in very different ways to the Hohokam. Recent evidence of flexible settlement and pottery production suggests a greater capacity of the Mimbres to respond to drought and economic change (Nelson et al. 2006), albeit at lower population densities (Nelson et al. 2016). Such long-term datasets can provide the depth required for researchers to examine discrete cases in a broader diachronic context and to explain the various limitations on a given society's social and cultural capacity to adapt (Butzer 2012; Spielmann et al. 2016).

The analysis of past disasters also has the potential to demonstrate a causal relationship between the pre-impact vulnerability of populations to social and environmental change and evidence of post-impact cultural change (Cooper and Sheets 2012; Riede 2014). Box 1 provides examples of disaster risk reduction (DRR) in contemporary and palaeosocietal contexts. Understanding how societies responded differently to extreme events, such as volcanic eruptions, provides a basis not only to assess socio-cultural limitations, but also suitability of anticipatory or post-impact adjustments to risk. With sufficient data resolution, archaeology and other historical sciences can provide empirical evidence of challenges associated with long-term adaptation to disasters and environmental change, whereas contemporary research relies on informed speculation on societal capacity to adapt to future, and hence unknown, environmental change. In turn, such experiments of history, with their known outcomes, can feed into the evidence-based construction of realistic disaster scenarios (Mazzorana et al. 2009; Riede 2017).

Box 1: The temporality of risk: Disaster Risk Reduction (DRR)

Disaster risk reduction (DRR) is a field concerned with risk reduction in human settlements in proximity to hydrometerological hazards, such as hurricane hotspots and mountainous areas prone to avalanches (Keiler et al. 2006; Fuchs et al. 2007), geophysical hazards, such as volcanic eruptions and tectonic zones (Smith 2013), and anthropogenic hazards, such as industrial and infrastructure hazards (November 2008). These fields receive substantial government funding and attention from the natural sciences, civil engineering and the social sciences for their roles in reducing societal risk via monitoring and prediction (Earle et al. 2012), hazard-response protocols (Alexander 2010), infrastructure design, and post-disaster relief (Alexander 1995, 1997). There is also a significant archaeological literature on past disasters (Riede 2014a, 2016, 2017; Riede 2017), and the long-term cultural responses to environmental change (Dugmore et al. 2013; Dow et al. 2013). Riede's (2014a) science of past disasters emphasises the potential of long-term cases, or completed experiments, for assessing 'possibilistic' (Clarke 2007, 2008) outcomes of volcanic eruptions on human populations, evaluating the spatio-temporal impacts of eruptions, and the long-term interplay of social contextual factors, impact event, and capacity to respond (Riede 2017)

Deep-time perspectives can illustrate the vulnerabilities of populations before and after eruption events to explain both the 'spatiality' (November 2008) and 'temporality' of risk (Riede 2017). Iceland, for example, is alert to the immediate effects of eruption events on nearby settlements, farming, and aviation (Donovan and Oppenheimer 2011). In contrast, transatlantic aviation between Europe and North America was unprepared for impacts associated with the 2010 eruption of Eyjafjallajökull (Lund and Benediktsson 2011). This was largely due to the unanticipated synergistic effects of a volcanic plume, meteorological conditions and a lack of appropriate crisis management (Alexander 2013; Inkpen 2016; Donovan and Oppenheimer 2012). From a DRR perspective, effective crisis response requires the identification of the far-reaching effects of such events on vulnerable social groups (Linkov et al. 2022a), 'critical infrastructures' (Linkov et al. 2022b), essential resources, and environmental stability (Kuklicke and Demeritt 2016). Vitally, it is often the frequency of hazards that conditions populations to risks (Lawson et al. 2012); the more frequent events occur, the more a population is required to adapt its behaviour (Rockman 2003, 2012). Therefore, the vulnerability of a population to low-frequency yet high-magnitude events may not be apparent until such an event takes place (Dugmore and Vésteinsson 2012). Long-term perspective that can more effectively include the complex social responses and spatial and temporal impacts of rare events (such as volcanic hazards) on past societies adds important context to the societal perception of risk.

Possibilistic Reasoning, Counterfactuals and Scenario Modelling

In modern ***adaptive management*** strategies many agencies and organizations have been strongly influenced by the Resilience Alliance's widely disseminated *Assessing Resilience in Social-Ecological Systems: Workbook for Practitioners* (2010) which emphasizes practices aimed at breaking out of path dependent management structures and accepting levels of uncertainty and risk as part of an ongoing process of assessment, application, and re-assessment. An example below taken from Washington State's criteria for evaluating and prioritizing adaptation options provides a useful example of the kinds of questions practitioners and policy makers are now asking. Note that most of these relevance questions have a historical component and will in practice be difficult to address with only a few decades of records to consult. All would benefit from contributions by scholars of the past (Table 2).

Adaptive management strategies and the recommendations of the *RA Workbook* (2010) are regularly connected to the process of scenario building as a means of coping with uncertain futures, often deliberately contemplating a range of "what if" counter-factual pasts to get a better understanding of an actual range of potential future outcomes (Levy 2008; Ison et al. 2014). Climate change response is increasingly seen as one of the ultimate "Wicked Problems" which defy effective problem formulation and resist simple engineering solutions that ignore the social and practical limits imposed by prior interventions and longer historical trends. Current

Table 2 Criteria for evaluating adaptation options. Adapted from Table 2.11 in Washington State 2010 Climate Response Strategy "Potential Criteria for evaluating and prioritizing adaptation options" (http://www.ecy.wa.gov.climatechange/2010TAG.htm)

Criteria	Relevance
Importance	What is at stake if we do nothing? Are changes likely to affect unique or valuable species, ecological functions, keystone environments, watersheds, treaty rights?
Urgency	What ae the costs of delaying action? Is it likely to cost more to implement later than now? Are the consequences of not acting now irreversible?
Co-Benefits	Are there benefits beyond the immediate adaptation goal? Will total benefits long term exceed the costs of implementation? Are costs and benefits equitably distributed across communities?
Feasibility	How feasible is the proposed action given existing laws, policies, and the political climate? How technically feasible is the action? Is there an opportunity to repurpose existing actions and strategies or will a completely new approach be required?
Robustness	What is the likelihood that the proposed action will be effective across the range of possible future scenarios? Does it allow for effective adaptive management?
Cost	How costly will the proposed action be in terms of time, money, staff, or other resources? Will this investment preclude other adaptation options or aid them?
Other	What impacts on greenhouse gas emissions? Equity of impacts and benefits across communities? Consistency with national laws and policies?

best practice in scenario building for forward planning emphasizes the need for wide stakeholder and knowledge holder participation in framing the initial questions and range of possible outcomes to avoid automatically privileging "common sense" perspectives that in practice often fatally constrain effective scenario design. There is a need to push the historical perspective in scenario building back beyond the decadal scale and to incorporate more diverse and detailed "lessons of history" delivered by knowledge holding communities experienced in handling the multiple practical and theoretical issues of understanding the past (Rounsevell and Metzger 2010). The engagement of history, environmental humanities, archaeology, and paleoecology in agency and organizational scenario building exercises and their participation in regular follow up assessment meetings may be a critical contribution point for these disciplines. While the "no analog" future may in fact present challenges never before faced by society, some social responses can be shown to be recurring across time and cultures and others can be identified rarely. Many past societies have reacted to local resource shortage by migration, regularly involving violence, and thus planners should build mobility (controlled and uncontrolled) as a likely feature of future social response into most scenarios. A common feature of large-scale, long-lasting, hegemonic, imperial, multi-cultural societies has been the creation of an inclusive elite sub-culture with shared language, taste in art, and use of material symbols to interconnect what may be very different local cultures in a common system that can balance diversity and shared values. Might promoting similar mixes of diversity with competence in participation in a shared elite culture gain support from past cases as a positive objective for "favorable outcome" scenario end-points?

Why?

Why not?

The past thus represents both a storehouse of completed experiments in human ecodynamics and an active resource for "what if" scenario construction and testing.

Policy Implications

One of the significant challenges for adaptation in policy and planning is the interplay between key concepts and terminology associated with the human dimensions of climate change and measuring progress in adaptation. The Global Center on Adaptation's (2020) *State and Trends in Adaptation report 2020* highlight among its top policy recommendations the need to improve measures and metrics for progress and improving the knowledge base required to inform adaptive planning. A similar challenge is highlighted in Ford et al.'s (2018: 193) review of climate change vulnerability research, critiquing the 'conceptual vagueness', siloed nature of research, and the 'static' nature of monitoring. This report and study identified the lack of conceptual clarity and ability to test and measure adaptation and vulnerability as a

significant barrier to effective adaptive planning. However, as we will argue, historical experiments offer analogues with which to examine, test and measure concepts over multiple temporal and spatial scales.

As explored in the previous section, natural experiments of history or, as some archaeologists say, completed experiments of the past, offer retrospective evidence of human–environment interaction over extended timescales (Redman 2005; Hartman et al. 2017). The benefit of this retrospective information is not only observable evidence of vulnerability and adaptation to climate variability and other exogenous changes (Nelson et al. 2016), but also the counterfactual questions that can be asked of different societies in the context of these changes (Carr 1964). Counterfactuals allow plausible questions to be asked regarding processes that may underly patterns of social and ecological change in a given context. These 'what if' questions also have an application in strategic planning, to determine plausible outcomes of different decisions and to plot a range of plausible scenarios (Jin et al. 2021).

One of the significant errors that has plagued historical and archaeological research in the early twenty-first century has been the assumption that deterministic and reductionist understandings of human–environment interaction will yield lessons about how to respond to environmental change in the future (*see for example* Diamond 1997, 2005). Such approaches have been critiqued for their limited emphasis on human agency, ingenuity and capacity in response to environmental challenges (McAnany and Yoffee 2010). But more importantly, the lack of dialogue with researchers of contemporary human vulnerability and adaptation has undermined the application of historical evidence. Jackson et al. (2018) emphasize the need for archaeologists to work in more active dialogues with researchers of contemporary global change, publish in interdisciplinary journals read by global change researchers and policymakers, and use their connections with museums and local communities to communicate archaeological relevance (Cooper and Sheets 2012; Hartman et al. 2017; Sigurðardóttir et al. 2019). First and foremost, archaeological and historical researchers need to carve out space for an effective dialogue with adaptation researchers and planners where relevant and insightful evidence about potential limits and barriers to adaptation can be identified. In this sense, knowledge of how to respond to uncertain futures can be co-produced.

Exercises in deep-time thinking have the potential to combine expertise from existing adaptation planning strategies and frameworks with historical evidence of adaptive continuity and change to co-produce qualitative scenarios (see Riede and Jackson 2020). Figure 1 visualizes the opportunity for collaborations that synthesize lessons from historical sciences with contemporary place-based research into vulnerability and adaptation. This figure illustrates the distributed evidence of long-term adaptation in the archaeological and historical record—evidence that has limited direct application to the present. By combining evidence of adaptative, capacities, limits and barriers, and path dependencies with existing planning, a range of potential scenarios could be tested. What if scenarios based on historical evidence could be tested using such scenarios in order to anticipate the unanticipated consequences of different adaptive strategies and physical and socio-economic constraints on the adaptive pathway (see Fig. 1). As noted earlier, the contingency of human responses

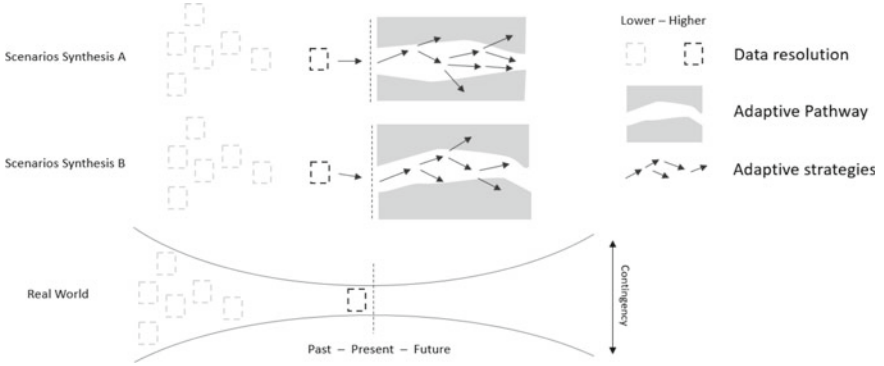

Fig. 1 Framework for scenario synthesis that combined historical scenarios and contemporary adaptive planning to consider a range of qualitative scenarios

to environmental change and the challenge of measuring vulnerability and adaptation are significant barriers to effective adaptive planning (Global Center on Adaptation 2020; Ford et al. 2018). Completed experiments of history can engage a largely unexploited network of disciplines capable of influencing co-production and planning of futures scenarios and anticipating barriers and limits to adaptation (see Hulme 2011).

Finally, it should be noted that adaptive planning, and environmental sustainability and sustainable development more broadly, are intergenerational challenges that, by definition, require an understanding of the interplay between continuity, including path dependent behaviors, and social and environmental change. Progressive approaches to policy and governance, including the Welsh government's Minister for Further Generations, already incorporate measures that think beyond current generations. Historical disciplines potentially have a significant and growing role to play in support of these foresight and planning efforts.

The Problems of Sustainability, Resilience, Transformation

Investigation of the human dimensions of climate change is a vast and contested field of study (Wigley et al. 1981; Huntington et al. 2007; Castree et al. 2014). The contestation of the field has been associated, in part, with the limited inclusion of the social sciences and humanities in global environmental assessments, such as the Intergovernmental Panel on Climate Change (IPCC) and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) (Hartman 2015; 2020), which has spurred debate about the limited consensus on global change terminology and associated concepts, especially among marginalized disciplines and knowledge domains (Hulme 2011; Castree 2017; Castree et al. 2021). The result has been a succession of pervasive but often nebulous concepts

that are indeed contested in specific disciplinary contexts, but insufficiently theorized and debated across disciplinary boundaries and sectors. *Sustainability*, *vulnerability*, *adaptation*, *resilience*, and *transformation*, as indeed the trope of *collapse*, are dominant concepts that receive significant credence and use, but minimal clarification across subjects focusing on impacts and adaptation to climate change (Blewitt 2018). Here we provide a brief micro-lineage of these contested terms and the challenges associated with their use.

Though the core ideas encapsulated in the concept of *sustainable development* were already current in the 1970s, arguably earlier in specific contexts (e.g. nature conservation and preservation), the term was first coined in 1980 in the *World Conservation Strategy: Living Resource Conservation for Sustainable Development*, published by the International Union for Conservation of Nature and Natural Resources, in cooperation with the World Wildlife Fund, the United Nations Environmental Programme, the Food and Agriculture Organization of the United Nations and UNESCO. The concept of sustainable development was distilled and popularized in more memorable form, however, in the 1987 report of the Brundtland Commission, *Our Common Future*, which characterized it as development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED). Since then the term has been the subject of significant debate. One refinement of the concept has been a growing preference in many fields of study and social endeavor for the term *sustainability* over the original term owing to the colonialist, exploitative, extractivist First-World/Third-World or Developed/Undeveloped World dichotomies on which the concept of *sustainable development* is so evidently predicated. After all, who or what is developing in the implicit subjectivity of the phrase?—or into whom or what else is it being developed in its implicit non-agentive passivity? The answer is hiding in plain sight, as the so-called undeveloped or underdeveloped world (more fully represented in the Global South) contrasts with a developed world (the more highly industrialized Global North) whose unsustainable growth, rapacious appetite for overconsumption and poorly restrained fossil-fuel energy burning during much of the 20th and now the early twenty-first centuries have led to a projected monthly average of well over 420 ppm of carbon dioxide in the Earth's atmosphere in 2021 (NOAA 2022).

The inherent challenge for sustainability and sustainable development has been the contradiction between economic growth and ecological health and flourishing, as well as the balance of meeting human needs within ecological constraints (Mahoney et al. 2022). The challenge of balancing needs with sustainable limits is common throughout definitions of sustainable development and reflected in Stefanovic's (2000) 'mediative thinking,' which balances antecedent factors shaping ecological constraints, economic development, social organization, and environmental values. Blewitt (2018) argues that the ambiguity of sustainability and sustainable development is also a strength, as a heuristic for balancing society, economy, and the environment.

Since the turn of the millennium, the literature on adaptation and vulnerability to climate change has boomed (Bassett and Fogelman 2013), but the use of this terminology has remained pervasive. Although the literature has grown significantly in

recent years, as Bassett and Fogelman (2013) explain, the characterizations of adaptation as 'adjustment' by the hazards school and 'reformist' by the political economy school have been dominant counterbalancing discourses since the 1970 and 1980s. These approaches to adaptation have been closely associated with vulnerability, with 'adjustment' adaptations tending to view vulnerability as the outcome of climate impacts, while 'reformist' adaptations are seen as the social and political contexts in which vulnerability to climate impacts are created (O'Brien et al. 2007). A more recent trend has been the view of 'transformative' adaptation as a corollary of an inadequate focus on the social context of vulnerability in political and economic systems (O'Brien 2018).

Transformation, as defined in IPCC *Assessment Report 5* (2014), is regarded as a "change in the fundamental attributes of natural and human systems… [reflecting] strengthened, altered, or aligned paradigms, goals, or values towards promoting adaptation for sustainable development". Feola (2015) draws attention to the conceptual vagueness and the remaining pervasiveness of the social transformation concept, noting that 'transformation' is largely used as a metaphor for fundamental change within a smaller problem-based literature, with the plural form reflecting a plural understanding of the concept. Transformation has, in many ways, inherited the same idiomatic pervasiveness that Anderson (2015) identifies in the concept of resilience, but it also has the potential to clarify concepts such as adaptation and address the weaknesses of resilience theory. The plurality and nuance that can be brought to these concepts by different disciplinary and theoretical perspectives has the potential to be a great strength, in both theoretical and applied contexts. However, these very qualities can also become derailing weaknesses when defining criteria are not carried over from one discipline or community of practice to another. Instead of stringent conceptual distinctions (reflecting how such terms may have been introduced in their original scientific contexts) that are rigorously upheld through close dialogue and mutual literacy-building activities among and across distinct disciplinary and research domains and other user communities, terms and concepts such as *sustainability*, *transformation*, *resilience* and *collapse* can be compromised by broad, loose or metaphorically fuzzy application in different parts of the science-policy-governance interface. The kinds of conceptual, semantic and even methodological slippages that occur as the terms cycle through a process from Mode 1 to Mode 2 research, feeding back into new Mode 1 contexts, effectively lead to a situation whereby these terms can mean a little of everything and, in other contexts, a whole lot of nothing the more they are used, generalized and popularized.

These terms have varied meanings for different users and communities of practice, which effectively leaves them devoid of universally comprehensible meanings over time the more they are coined in ever widening contexts and transactions. Series of semantic slippages occur between user communities, in the move from Mode 1 research to the science policy-interface, then onward to Mode 2 research. In new interfaces from science to policy to governance, planning and social-environmental management they become, progressively, ever more poorly signifying signifiers through these transactions of use and abuse. In the end, terms such as sustainability, resilience, transformation and adaptation move so far from their definitions as set

out and refined when first they were coined in their original scientific contexts that, through various feedback loops (usage by policymakers, different societal stakeholders with different and sometimes even opposing interests and priorities), their meanings as established originally in rigorous scientific discourse/s is effectively washed away. Hence the phenomena of greenwashing (the 'Good Anthropocene', 'sustainable work,' etc.) or empty policy jargon easily co-opted for the transactional use *de jour*.

We highlight this pervasiveness and terminological confusion in order to signal an opportunity offered by the increased engagement of history, archaeology, and the environmental humanities in global change research (see Hartman 2015, 2020; Hartman et al. 2017; Holm et al. 2015; Jackson et al. 2018). The role of historical disciplines, including archaeology, has been highlighted in identifying cross-scale interactions (between society and the environment) and longitudinal (process-based) understandings of vulnerability that address some of the existing conceptual inadequacies (Ford et al. 2018). More active multilateral conversations and research collaborations among established global change research disciplines and historically under-engaged disciplines in qualitative humanities and social sciences, especially transdisciplinary site-based research approaches such as those found in historical ecology (Crumley 1994, 2007, 2018a, b) richly blending (qualitative and quantitative) research methodologies, can provide valuable footholds and models of collaboration to help overcome, and perhaps even begin to remediate, problems of knowledge exchange deficit through transactional semantic slippage of terminology and conceptual abuse.

Conclusion

The ambition to use past cases of environmental crisis and social-ecological change in efforts to address future risks has perhaps never been greater than in the present era of rapid environmental and social change. However, this ambition requires that researchers and scholars in the historical sciences examine, and face head on, the implications of any number of sticky questions. In concluding we suggest some open-ended questions as the basis for closer scrutiny, further analysis and continued creative engagement:

1. What role can past cases of social-ecological system disturbance play in helping scientists, policymakers and environmental managers address present and future vulnerabilities?

   The relevance of archaeological and historical information, as we have discussed in this chapter, has all too often been lost in the hyperbole of collapse discourse, but to learn from the past a clear dialogue between historical researchers and global change science, policy and practice is needed.

2. Why is it important to bring historical cases of social and environmental change into our efforts to address present and future challenges posed by processes of abrupt change?

   Historical studies scholars might regard the answer to this question as self-evident; however, in light of the insufficient involvement of historians, archaeologists and other deeper-time historical studies scholars in scientific assessment, the policy-science interface and governance efforts more generally focused on the challenges of global change, it seems anything but clear where and how historical casework may fit into broader efforts to apply knowledge of past changes to 21st century risk and vulnerability mitigation work as it is actually carried out today.
3. What clear limits might there be to the use of historical cases as guides to help define, address and plan for vulnerability scenarios?

   The most obvious limitations for historical disciplines have been the pitfalls of historicism and environmental determinism (see Popper 1956; Hulme, 2011), but they are all too easy to fall into. It is far easier to draw direct analogies that ignore context, nuance and socio-environmental complexity. However, there is far more value to be gained from a wide range of scenarios and social situations than (over) simplistic lessons that neglect human agency and the co-evolution of culture, society and the environment.
4. How can we as historical research scholars take account of those limitations to avoid producing noise rather than genuinely useful knowledge (a usable past) in efforts to better prepare for foreseeable risks, even regime-changing system shocks?

   Active engagement with researchers of contemporary global environmental change to co-produce useable knowledge is a pro-active opportunity for historical researchers to identify gaps and solutions using historically informed but contextualized knowledge (see Jackson et al. 2018).
5. What can we do to more readily recognize and avoid disjunctures in scientific/theoretical versus practical/applied use of central concepts from sustainability studies and resilience science, especially if these effectively lead to the prevalence of such noise among diverse key communities of practice?;

   Some obvious cases in point are the ways in which the concepts of “resilience” or “collapse” are employed in the respective fields of sustainability science or historical sciences, on the one hand, versus how they tend to be understood and acted upon by policymakers, planners or emergency response agencies on the other hand. As suggested in Ford et al. (2018), we should seize the opportunity to clarify and improve our understanding of concepts in sustainability studies and resilience science through engagement with historical disciplines. These completed natural experiments can test the applications of concepts to different geographical and social situations and extend the temporal horizon of concepts such as vulnerability, adaptation and resilience.

6. What steps can help refine the ways in which historical cases may be used to better understand and plan for vulnerability scenarios?

   Where, in other words, can we efficiently direct our efforts to operationalize historical cases so that they can help scientists, scholars from non-historical disciplines, policymakers, societal planners and environmental managers understand the human-dimensions of environmental change?
7. Can we build viable wider-purpose toolkits for emergency response scenarios or social-ecological system planning from specific lessons and case studies of past environmental change at various scales?

   Or do we need to be thinking in other ways that take better account of the multi-scalar complexity and irreproduceability of natural, social and technological causes and effects in specific (always contingent) contexts of social-ecological system change.
8. Can we provide different kinds of knowledge takeaways from historical cases to policymaking and governance actors?

   Is there a way to offer greater qualitative layering or contextual nuance to risk and vulnerability scenarios derived from models of system change according to the dominant models of resilience theory and sustainability science in use today?
9. What might these look like ideally and how might they function?

   What future does the past have in our efforts to better prepare for the major societal challenges that await us?

References

Adamson GC, Hannaford MJ, Rohland EJ (2018) Re-thinking the present: the role of a historical focus in climate change adaptation research. Glob Environ Chang 48:195–205

Aimers JJ (2007) What maya collapse? Terminal classic variation in the Maya lowlands. J Archaeol Res 15(4):329–377

Alexander D (1997) The study of natural disasters, 1977–97: Some reflections on a changing field of knowledge. Disasters 21(4):284–304

Alexander DE (1995). A survey of the field of natural hazards and disaster studies. In: Geographical information systems in assessing natural hazards. Springer, Dordrecht, pp 1–19

Alexander DE (2010) The L'Aquila earthquake of 6 April 2009 and Italian Government policy on disaster response. J Nat Resour Policy Res 2(4):325–342

Alexander DE (2013) Resilience and disaster risk reduction: an etymological journey. Nat Hazards Earth Syst Sci 13(11):2707–2716

Allana S, Clark A (2018) Applying meta-theory to qualitative and mixed-methods research: a discussion of critical realism and heart failure disease management interventions research. Int J Qual Methods. https://doi.org/10.1177/1609406918790042

Allen CR, Angeler DG, Chaffin BC, Twidwell D, Garmestani A (2019) Resilience reconciled. Nat Sustain 2(10):898–900

Anderson B (2015) What kind of thing is resilience?. Politics 35(1):60–66

Barrett JH (2018) Medieval fishing and fish trade. In: Gerrard C, Gutiérrez A (eds) The Oxford handbook of later medieval archaeology in Britain. Oxford, Oxford University Press
Barry A, Born G (2013) Interdisciplinarity: reconfigurations of the social and natural sciences. In: Barry A, Born G (eds) Interdisciplinarity: reconfigurations of the social and natural sciences. London, Routledge
Bassett TJ, Fogelman C (2013) Déjà vu or something new? The adaptation concept in the climate change literature. Geoforum 48:42–53
Blewitt J (2018) Understanding sustainable development. Routledge, Oxon
Bocinsky RK, Kohler T (2014) A 2000-year reconstruction of the rain-fed maize agricultural niche in the US Southwest. Nat Commun 5:5618. https://doi.org/10.1038/ncomms6618
Boivin NL, Zeder MA, Fuller DQ, Crowther A, Larson G, Erlandson JM, Denham T, Petraglia MD (2016) Ecological consequences of human niche construction: examining long-term anthropogenic shaping of global species distributions. Proc Natl Acad Sci 113(23):6388–6396
Bostrom N, Milan C (eds) (2008) Global catastrophic risks. Oxford UP
Brewington S, Hicks M, Edwald et al (2015) Islands of change vs. islands of disaster: managing pigs and birds in the Anthropocene of the North Atlantic. The Holocene 25(10):1676–1684
Burke P (2015) The French historical revolition: the annales school 1929–214, 2nd edn. Polity, Cambridge
Butzer KW (2012) Collapse, environment, and society. Proc Natl Acad Sci 109(10):3632–3639
Butzer KW, Endfield GH (2012) Critical perspectives on historical collapse. Proc Natl Acad Sci 109(10):3628–3631
Carr EH (1964) What is history? Penguin, Hammondsworth
Castree N (2014) The anthropocene and the environmental humanities: extending the conversation. Environ HumIties 5(1):233–260
Castree N (2016) Geography and the new social contract for global change research. Trans Inst Br Geogr 41(3):328–347
Castree N (2017) Global change research and the "People Disciplines": towards a new dispensation. South Atlantic Quaterly 116(1):55–67
Castree N, Adams WM, Barry J, Brockington D, Büscher B, Corbera E, Demeritt D, Duffy R, Felt U, Neves K, Newell P (2014) Changing the intellectual climate. Nat Clim Chang 4(9):763–768
Castree N, Bellamy R, Osaka S (2021) The future of global environmental assessments: making a case for fundamental change. Anthropocene Rev 8(1):56–82
Chakrabarty D (2009) The climate of history: four theses. Crit Inq 35(2):197–222
Clarke L (2007) Thinking possibilistically in a probabilistic world. Significance 4(4):190–192
Clarke L (2008) Possibilistic thinking: a new conceptual tool for thinking about extreme events. Soc Res 669–690
Collins HM, Evans R (2002) The third wave of science studies: studies of expertise and experience. Soc Stud Sci 32(2):235–296
Cooper J, Sheets P (eds) (2012) Surviving sudden environmental change: lessons from archaeology. University of Colorado Press, Boulder
Crumley CL (ed) (1994) Historical ecology: cultural knowledge and changing landscapes. School of american research advanced seminar. Santa Fe: School of American Research
Crumley CL (2007) Historical ecology: integrated thinking at multiple temporal and spatial scales. The world system and the earth system: global socio-environmental change and sustainability since the Neolithic. Alf H, Carole C (eds), pp 15–28. Walnut Creek CA, Left Coast Press
Crumley CL (2018a) Historical ecology and the longue durée. In: Paul S, Jon M, Carole L, Crumley C, Carole L, Tommy L, Anna W (eds) Issues and concepts in historical ecology: the past and future of landscapes and regions, pp 13–40. Cambridge GB, Cambridge University Press
Crumley CL (2018b) New paths into the anthropocene: applying historical ecologies to the human future. The oxford handbook of historical ecology and applied archaeology, Isendahl C, Stump D (eds), pp 6–20. Oxford, Oxford University Press. (Online 2015, published)
d'Alpoim Guedes J, Crabtree SA, Bocinsky RK, Kohler TA (2016) Twenty-first century approaches to ancient problems: climate and society. Proc Natl Acad Sci 113(51):14483–14491

Dawdy SL (2009) Millennial Archaeology: Locating the Discipline in the Age of Insecurity/Doomsday Confessions. Archaeological Dialogues 16(2):131–142
Dawson T (2015) Eroding archaeology at the coast: How a global problem is being managed in Scotland, with examples from the Western Isles. in Journal of the North Atlantic: 2010 Hebridean Archaeology Forum. vol. Special Volume 9, Eagle Hill Publications, Steuben, Maine United States, pp. 83–98. https://doi.org/10.3721/037.002.sp905
Dawson TC, Nimura C, Lopez-Romero E, Daire M-Y (eds) (2017) Public archaeology and climate change. Oxbow, Oxford
Diamond J (1997) Guns, germs and steel. Vintage Classics, London
Diamond J (2005) Collapse: how societies choose to fail or survive. Penguin, London
Diamond J, Robinson JA (2010) Natural Experiments of History. Harvard University Press
Dietz T, Ostrom E, Stern PC (2003) The struggle to govern the commons. Science 302(5652):1907–1912
Donovan A and Oppenheimer C (2011) The 2010 Eyjafjallajökull eruption and the reconstruction of geography. Geogr J 177(1):4–11
Donovan A and Oppenheimer C (2012) Governing the lithosphere: Insights from Eyjafjallajökull concerning the role of scientists in supporting decision-making on active volcanoes. J Geophys Res 117:B03214
Dow K, Berkhout F, Preston BL, Klein RJT, Midgley G, Shaw MR (2013) Limits to adaptation. Nat Clim Change 3(4):305–307
Dugmore A, Vésteinsson O (2012) Black sun, high flame, and flood: volcanic hazards in Iceland. Surviv Sudd Environ Chang 67–90
Dugmore AJ, Thomas HM, Richard S, Christian KM, Konrad S, Christian K (2013) 'Clumsy solutions' and 'Elegant failures': lessons on climate change adaptation from the settlement of the North Atlantic islands in: a changing environment for human security: transformative approaches to research, policy and action. Linda S, O'Brien K, Johanna W (eds) Chapter 38. Routledge, UK, London
Dunne JA, Maschner H, Betts MW, Huntly N, Russell R, Williams RJ, Wood SA (2016) The roles and impacts of human hunter-gatherers in North Pacific marine food webs. Sci Rep 6(1):1–9
Dunning T (2008) Improving causal inference: strengths and limitations of natural experiments. Polit Res Q 61(2):282–293
Dunning T (2012) Natural Experiments in the Social Sciences. Cambridge University Press, Cambridge
Engelhard GH, Thurstan RH, MacKenzie BR, Alleway HK, Bannister RCA, Cardinale M, Clarke MW, Currie JC, Fortibuoni T, Holm P, Holt SJ, Mazzoldi C, Pinnegar JK, Raicevich S, Volckaert FAM, Klein ES, Lescrauwaet A-K (2015) ICES meets marine historical ecology: placing the history of fish and fisheries in current policy context. ICES J Mar Sci. https://doi.org/10.1093/icesjms/fsv219
Erlandson JM, Braje TJ (2013) Archeology and the Anthropocene. Anthropocene 4:1–7
Feola G (2015) Societal transformation in response to global environmental change: a review of emerging concepts. Ambio 44(5):376–390
Flecknoe D, Wakefield BC, Simmons A (2018) Plagues & wars: the 'Spanish Flu' pandemic as a lesson from history. Med Confl Surviv 34(2):61–68. https://doi.org/10.1080/13623699.2018.1472892
Ford JD, Pearce T, McDowell G, Berrang-Ford L, Sayles JS, Belfer E (2018) Vulnerability and its discontents: the past, present, and future of climate change vulnerability research. Clim Change 151(2):189–203
Fuchs S, Heiss K, Hübl J (2007) Towards an empirical vulnerability function for use in debris flow risk assessment. Nat Hazards Earth 7(5):495–506
Geels FW (2012) A socio-technical analysis of low-carbon transitions: introducing the multi-level perspective into transport studies. J Transp Geogr 24:471–482

Global Center on Adaptation (2020) State and trends in adaptation report 2020. https://gca.org/wp-content/uploads/2021/03/GCA-State-and-Trends-Report-2020-Online-3.pdf. Last Accessed 11 Aug 2021

Haider LJ, Schlüter M, Folke C, Reyers B (2021) Rethinking resilience and development: a coevolutionary perspective. Ambio 1–9

Haldon J, Mordechai L, Newfield TP, Chase AF, Izdebski A, Guzowski P, Labuhn I, Roberts N (2018) History meets palaeoscience: Consilience and collaboration in studying past societal responses to environmental change. Proc Natl Acad Sci 115(13):3210–3218

Hambrecht G, Anderung C, Brewington S, Dugmore A, Edvardsson R, Feeley F, Gibbons K, Harrison R, Hicks M, Jackson R, Ólafsdóttir GÁ, Rockman M, Smiarowski K, Streeter R, Szabo V, McGovern T (2018) Archaeological sites as distributed long-term observing networks of the past (DONOP). Quatern Int. https://doi.org/10.1016/j.quaint.2018.04.016

Hartley LP (1953) The go-between. Hamish Hamilton

Hartman S, Ogilvie AEJ, Ingimundarson JH, Dugmore AJ, Hambrecht G, McGovern TH (2017) Medieval Iceland, Greenland and the new human condition: a case study in integrated environmental humanities. Glob Planet Chang 156(2017):123–139. https://doi.org/10.1016/j.gloplacha.2017.04.007

Hartman S (2015) Unpacking the black box: the need for integrated environmental humanities. Future earth blog. Future earth, 3 June 2015. Web. 14 May, 2021. https://futureearth.org/2015/06/03/unpacking-the-black-box-the-need-for-integrated-environmental-humanities-ieh/

Hartman S (2016) Revealing environmental memory: what the study of medieval literature can tell us about long-term environmental change. In: Biodiverse Nr, 2 2016 (online)

Hartman S (2020) Into the fray: a call for policy-engaged and actionable environmental humanities. Ecozon@ 11(2):187–199

Hegmon M (ed) (2017) The give and take of sustainability: archaeological and anthropological perspectives on tradeoffs. United Kingdom, Cambridge University Press

Hendrickson DC, Mcmaster HR (1997) Dereliction of duty: Johnson, Mcnamara, the joint chiefs of staff, and the lies that led to Vietnam. Foreign Aff 76:153

Hess GR (1994) The unending debate: historians and the Vietnam war. Dipl Hist 18(2):239–264. https://doi.org/10.1111/j.1467-7709.1994.tb00612.x

Hicks M, Einarsson Á, Anamthawat-Jónsson K, Edwald Á, Friðriksson A, Þórsson ÆÞ, McGovern TH (2016) Community and conservation: documenting millennial scale sustainable resource use at lake Mývatn Iceland. In: Isendahl C, Stump D (eds) Handbook of historical ecology and applied archaeology. Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199672691.013.36

Hilding-Rydevik T, Jon M, Carina G (2018) Baselines and the shifting baselines syndrome-exploring frames of reference in nature conservation. In: Carole C, Tommy L, Anna W (2018) Issues and concepts in historical ecology: the past and future of landscapes and regions, pp 112–144. Cambridge UP

Hochrainer-Stigler S, Colon C, Boza G, Brännström Å, Linnerooth-Bayer J, Pflug G, Dieckmann U (2020) Measuring, modeling, and managing systemic risk: the missing aspect of human agency. J Risk Res 23(10):1301–1317

Hoffman SM, Oliver-Smith A, Button GV (2001) Catastrophe & culture: the anthropology of disaster. School of American Research Press

Holm P, Adamson J, Huang H, Kirdan L, Kitch S, McCalman I, Ogude J, Ronan M, Scott D, Thompson KO, Travis C, Wehner K (2015) Humanities for the environment—a manifesto for research and action. Humanities 4(4):977–992

Hudson MJ, Aoyama M, Hoover KC, Uchiyama J (2012) Prospects and challenges for an archaeology of global climate change. Wiley Interdiscip Rev Clim Change 3:313–328

Hulme M (2011) Meet the humanities. Nat Clim Change 1(4):177–179

Huntington HP, Hamilton LC, Nicholson C, Brunner R, Lynch A, Ogilvie AEJ, Voinov A (2007) Towards understanding the human dimensions of the rapidly changing Arctic system: insights and approaches from five HARC projects. Reg Environ Change 7(4):173–186

Hynes W, Trump B, Love P, Linkov I (2020) Bouncing forward: a resilience approach to dealing with COVID-19 and future systemic shocks. Environ Syst Decis 40:174–184
Hynes W, Trump BD, Kirman A, Haldane A, Linkov I (2022) Systemic resilience in economics. Nature Physics 18(4):381–384
ICOMOS (2019) The future of our pasts: engaging cultural heritage in climate action. ICOMOS Climate Change and Heritage Working Group
Inkpen R (2016) 'Riskscapes' as a heuristic tool for understanding environmental risks: the Eyjafjallajokull volcanic ash cloud of April 2010. Risk Management 18(1):47–63
IPCC (2014) Climate change 2014: synthesis report. Contribution of working groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change (Core Writing Team, Pachauri RK, Meyer LA (eds)), p 151. IPCC, Geneva, Switzerland
IRGC (2018) IRGC guidelines for the governance of systemic risks. International Risk Governance Center (IRGC)
IUCN (1980) World conservation strategy: living resource conservation for sustainable development. International Union for Conservation of Nature and Natural Resources (IUCN-UNEP-WWF)
Iuga A, Anna W, Bogdan I, Monica S, Haakan T (2018) Rural communities and traditional ecological knowledge. In: Carole C, Tommy L, Anna W (eds) Issues and concepts in historical ecology: the past and future of landscapes and regions, pp 84–112. Cambridge UP
Izdebski A, Holmgren K, Weiberg E, Stocker SR, Buentgen U, Florenzano A, Gogou A, Leroy SA, Luterbacher J, Martrat B, Masi A (2016) Realising consilience: how better communication between archaeologists, historians and natural scientists can transform the study of past climate change in the Mediterranean. Quat Sci Rev, 136:5–22
Jackson R, Dugmore A, Riede F (2017) Towards a new social contract for archaeology and climate change adaptation. Archaeol Rev Camb 32(2):197–221
Jackson RC, Dugmore AJ, Riede F (2018) Rediscovering lessons of adaptation from the past. Glob Environ Chang 52:58–65
Jin AS, Trump BD, Golan M, Hynes W, Young M, Linkov I (2021) Building resilience will require compromise on efficiency. Nature Energy 6(11):997–999
Keiler M, Sailer R, Jörg P, Weber C, Fuchs S, Zischg A, Sauermoser S (2006) Avalanche risk assessment–a multi-temporal approach, results from Galtür, Austria. Nat Hazards Earth Syst Sci 6(4):637–651
Kintigh, K, Altschul, J, Beaudry, M, Drennan, R, Kinzig, A, Kohler, T, Limp, W, Maschner, H, Michener, W, Pauketat, T, Wright, H and Zeder, M. (2014a). Grand Challenges for Archaeology. Proceedings of the National Academy of Sciences 111:879–880
Kintigh KW, Altschul JH, Beaudry MC, Drennan RD, Kinzig AP, Kohler TA, Limp WF, Maschner HDG, Michener WK, Pauketat TR, Peregrine P, Sabloff JA, Wilkinson TJ, Wrights HT, Zeder MA (2014b) Gran challenges for archaeology. Am Antiq 79(1):5–24
Kohler TA (2012) Social evolution, hazards, and resilience: some concluding thoughts. In Cooper J, Sheets P (eds) Surviving sudden environmental change: answers from archaeology. Boulder, University of Colorado Press
Kohler TA, Rockman M (2020) The IPCC: a primer for archaeologists. Am Antiq 85(4):627–651
Kohler TA, Smith ME (2018) Ten thousand years of inequality. Arizona University Press
Kohler TA, Bocinsky RK, Cockburn TA, Robinson CE, Kane AE (2012) Modelling Prehispanic Puebo societies in their ecosystems. Ecol Model 241:30–41
Khong K, Yuen F (1990) Analogies at war: Korea, Munich, Dien Bien Phu, and the Vietnam decisions of 1965. Princeton
Kuklicke C, Demeritt D (2016) Adaptive and risk-based approaches to climate change and the management of uncertainty and institutional risk: the case of future flooding in England. Glob Environ Chang 37:56–68
Kwok R (2017) Historical data: hidden in the past. Nature 549(7672):419–421

Lawson IT, Swindles GT, Plunkett G, Greenberg D (2012) The spatial distribution of Holocene cryptotephras in northwest Europe since 7 ka: implications for understanding ash fall events from Icelandic eruptions. Quat Sci Rev 41:57–66
Levy JS (2008) Counterfactuals and case studies. In: Box-Steffensmeier JM, Brady HE, Collier D (eds) The Oxford handbook of political methodology. Oxford, Oxford University Press
Linkov I, Trump B, Kiker G (2022a) Diversity and inclusiveness are necessary components of resilient international teams. HumIties Soc Sci Commun 9(1):1–5
Linkov I, Trump B, Trump J, Pescaroli G, Mavrodieva A, Panda A (2022b) Stress-test the resilience of critical infrastructure. Nature 603(7902): 578–578
Loyn D (2009) In Afghanistan: two hundred years of british, Russian, and American Occupation. Macmillan Press NY
Lund KA, Benediktsson K (2011) Inhabiting a risky Earth: the Eyjafjallajökull eruption in 2010 and its impacts. Anthropol Today 27(1):6–9
Mahony M, Hulme M (2012) The colour of risk: exploration of the IPCC's "Burning Embers" diagram. Spontaneous Gener J Hist Philos Sci 6(1):75–89
Mahoney E, Golan M, Kurth M, Trump BD, Linkov I. (2022). Resilience-by-Design and Resilience-by-Intervention in supply chains for remote and indigenous communities. Nature Communications 13(1): 1–5
Marks RB (2015) The origins of the modern world: a global and environmental narrative form the fifteenth to the twenty-first century. Rowman and Littlefield, London
Mazzorana B, Hübl J, Fuchs S (2009) Improving risk assessment by defining consistent and reliable system scenarios. Nat Hazards Earth Syst Sci 9(1):145–159
McAnany PA, Yoffee N (2010) Questioning collapse: human resilience, ecological vulnerability, and the aftermath of empire. Cambridge University Press, Cambridge
Meadows, Donnella H., Meadows, Dennis L., Randers, Jørgen and Behrens, William W. III (1972) The Limits to Growth: A report for the Club of Rome's project The Predicament of Mankind. Potomac Associates – Universe Books.
Meyer WJ, Crumley CL (2011) Historical ecology: using what works to cross the divide. Atlantic Europe in the first millennium BC: crossing the divide. In: Tom M, Lois A (eds), pp 109–134. Oxford, Oxford University Press
Middleton G (2017) Understanding collapse: ancient history and modern myths. Cambridge University Press, Cambridge
Middleton GD (2012) Nothing lasts forever: environmental discourses on the collapse of past societies. J Archaeol Res 20(3):257–307
Middleton GD (2017) The show must go on: collapse, resilience, and transformation in 21st-century archaeology. Rev Anthropol 46(2–3):78–105
Moen J, Keskitalo ECH (2010) Interlocking panarchies in multi-use boreal forests in Sweden. Ecol Soc 15(3):17
Moxnes JF, Christophersen OA (2008) The Spanish flu as a worst case scenario? Microb Ecol Health Dis 20(1):1–26. https://doi.org/10.1080/08910600701699067
Murphy JT, Crumley C (eds) (2021) If the past teaches, what does the future learn? Ancient urban regions and the durable future. Research in urbanism series, delft school of architecture. TU Delft OPEN Publishing
Nelson MC, Hegmon M, Kintigh KW, Kinzig AP, Nelson BA, Anderies JM, Abbott DA, Spielmann KA, Ingram SE, Peeples MA, Kulow S, Strawhacker CA, Meegan CA (2012) Long-term vulnerability and resilience: three examples from archaeological study in the Southwestern United States and Northern Mexico. In: Cooper J, Sheets P (eds) Surviving sudden environmental change: answers from archaeology. University of Colorado Press, Boulder
Nelson MC, Hegmon M, Kulow S, Schollmeyer KG (2006) Archaeology and ecological perspectives on reorganization: a case study from the Mimbres region of the US Southwest. Am Antiq 71(3):403–432
Nelson MC, Ingram SE, Dugmore AJ, Streeter R, Peeples MA, McGovern TH, Hegmon M, Spielmann KA, Simpson IA, Strawhacker C, Comeau LE, Torvinen A, Madsen CK, Hambrecht G,

Smiarowski K (2016) Climate changes, vulnerabilities, and food security. Proc Natl Acad Sci 113(2):298–303
Nelson MG, Kinzig AP, Arneborg J, Streeter R, Ingram SE (2017) 'Vulnerability to Food Insecurity: tradeoffs and Their Consequences'. In: Hegmon M (ed) The Give and Take of Sustainability: Archaeological and Anthropological Perspectives on Tradeoffs. Cambridge University Press, Cambridge
Nixon R (2011) Slow violence and the environmentalism of the poor. Harvard University Press, Cambridge, Mass
NOAA (2022) Carbon dioxide now more than 50% higher than pre-industrial levels. National Oceanic and Atmospheric Administration website. https://www.noaa.gov/news-release/carbon-dioxide-now-more-than-50-higher-than-pre-industrial-levels. 3 June 2022. Accessed 7 June 2022
November V (2008) Spatiality of risk. Environ Plan A 40(7):1523–1527
Nowotny H, Scott PB, Gibbons MT (2013) Re-thinking science: knowledge and the public in an age of uncertainty. Polity Press, Cambridge
O'Brien K (2018) Is the 1.5 C target possible? Exploring the three spheres of transformation. Curr Opin Environ Sustain 31:153–160
O'Brien K, Eriksen S, Nygaard LP, Schjolden ANE (2007) Why different interpretations of vulnerability matter in climate change discourses. Climate policy 7(1):73–88
Ogilvie AE (2010) Historical climatology, climatic change, and implications for climate science in the twenty-first century. Climatic Change 100(1):33–47
Oliver-Smith A, Hoffman SM, Hoffman S (eds) (2020) The angry earth: disaster in anthropological perspective. Routledge
Palma-Oliveira JM, Trump BD, Wood MD, Linkov I (2018) Community-driven hypothesis testing: a solution for the tragedy of the anticommons. Risk Anal 38(3):620–634
Popper K (1956) The poverty of historicism. Routledge, London
Redman CL (2005) Resilience theory in archaeology. Am Anthropol 107:70–77
Richer S, Stump D, Marchant R (2019) Archaeology has no Relevance. Internet Archaeol 53. https://doi.org/10.11141/ia.53.2
Riede F (2006) The Scandinavian connection: the roots of darwinian archaeology in 19th-century Scandinavian archaeology. Bull Hist Archaeol 16(1)
Riede F (2014a) Towards a science of past disasters. Natural Hazards 71(1):335–362
Riede F (2014b) Climate models: use in archaeology. Nature 513(7518):315
Riede F (2017) Past-Forwarding Ancient Calamities: Pathways for Making Archaeology Relevant in Disaster Risk Reduction Research, Humanities, vol. 6, no. 4, 79, pp. 1–25. https://doi.org/10.3390/h6040079
Riede F, Andersen P, Price N (2016) Does archaeology need an ethical promise? World Archaeol 48(4):466–481
Riede F, Jackson RC (2020) Do deep-time disasters hold lessons for contemporary understandings of resilience and vulnerability? The case of the laacher see volcanic eruption. In: Sheets P, Riede F (eds) Going forward by looking back: archaeological Perspectives on socio-ecological crisis, response, and collapse. Berghahn Books, New York
Rockman M (2003) 'Knowledge and learning in the archaeology of colonization'. In: Rockman M, Steele J. (eds) Colonization of Unfamiliar Landscapes: The archaeology of adaptation. Routledge, London
Rockman M (2012) 'The Necessary Roles of Archaeology in Climate Change Mitigation and Adaptation'. In: Rockman M, Flatman J (eds) Archaeology in Society. Springer, New York
Rockman M, Hritz C (2020) Expanding use of archaeology in climate change response by changing its social environment. Proc Natl Acad Sci 117(15):8295–8302. https://doi.org/10.1073/pnas.1914213117
Rolett B, Diamond J (2004) Environmental predictors of pre-European deforestation on Pacific islands. Nature 431(7007):443–446
Rounsevell MD, Metzger MJ (2010) Developing qualitative scenario storylines for environmental change assessment. Wiley Interdiscip Rev Clim Chang 1(4):606–619

Ruddiman WF (2013) The anthropocene. Annu Rev Earth Planet Sci 41:45–68
Ruddiman WF (2003) The anthropogenic greenhouse era began thousands of years ago. Clim Change 61:261–293
Ruddiman WF (2007) The early anthropogenic hypothesis: Challenges and responses. Rev Geophys 45(4). https://doi.org/10.1029/2006RG000207
Sachs J (2020) The Ages of Globalization. Columbia University Press, New York
Samuelson W, Zeckhauser R (1988) Status quo bias in decision making. J Risk Uncertain 1(1):7–59
Sigurðardóttir R, Newton AJ, Hicks MT, Dugmore AJ, Hreinsson V, Ogilvie AE, Júlíusson ÁD, Einarsson Á, Hartman S, Simpson IA, Vésteinsson O (2019) Trolls, water, time, and community: resource management in the Mývatn District of Northeast Iceland. In: Ludomir L, Thomas M (eds) Global perspectives on long term community resource management, pp 77–101. Springer Co, NY
Sinclair P, Moen J, Crumley CL (2018) Historical ecology and the longue durée. Crumley CL, Tommy L, Anna W (eds) Issues and concepts in historical ecology: the past and future of landscapes and regions, pp 13–40. Cambridge, UK, Cambridge University Press
Smith BD and Zeder MA (2013) The onset of the anthropocene. Anthropocene 4:8–13
Smith K (2013) Environmental hazards: assessing risk and reducing disaster. Routledge, London
Smith ML (2014) Citizen science in archaeology. Am Antiq 749–762
Spielmann K, Peeples MA, Glowacki DM, Dugmore A (2016) Early warning signals of social transformation: a case study from the US Southwest. PLoS One 11(10):1–18
Stefanovic IL (2000) Safeguarding our common future: rethinking sustainable development. New York University Press, New York
Steffen PJC (2003) How long have we been in the Anthropocene era? Clim Change 61(3):251
Steffen W, Broadgate W, Deutsch L, Gaffney O, Ludwig C (2015) The trajectory of the Anthropocene: the great acceleration. Anthropocene Rev 2(1):81–98
Steffen W, Grinevald J, Crutzen P, McNeill J (2011) The anthropocene: conceptual and historical perspectives. Philos Trans R Soc A Math Phys Eng Sci 369(1938):842–867
Stump D (2013) On applied archaeology, indigenous knowledge, and the usable past. Curr Anthropol 54:268–298
Stump D, Richer S (2017) 'Terraces are good, but sediment traps are better'. AAREA Policy Brief No. 1, University of York
Tainter JA (1988) The collapse of complex societies. Cambridge University Press, Cambridge
Tainter J (2003) A framework for sustainability. World Futur J New Parad Res 59(3–4):213–223
Thaler R and Sustein C (2008) Nudge: improving decisions about health, wealth, and happiness. Penguin, London
Trigger B (2006) A history of archaeological thought. Cambridge University Press, Cambridge
UN SDG (2021) Sustainable development goals decade of action. https://www.un.org/sustainabledevelopment/decade-of-action/. Last Accessed 17 May 21. (Online)
UNESCO (2020a) Cities, climate and culture: the urban research agenda in the upcoming IPCC Co-sponsored expert meeting on culture, heritage and climate change. https://whc.unesco.org/en/events/1547/. Last Accessed 20 May 21. (Online)
UNESCO (2020b) Proposal for the establishment of BRIDGES as a MOST sustainability science coalition. https://unesdoc.unesco.org/ark:/48223/pf0000372656. Last Accessed 20 May 21. (Online)
Urry J (2003) Global complexity. Polity, London
Urry J (2007) Mobility. Polity, London
Waldman M (2013) System failure: the underlying causes of US policy-making errors in Afghanistan. Int Aff 89(4):825–843. https://doi.org/10.1111/1468-2346.12047
Walker B, Salt D (2012) Resilience thinking: sustaining ecosystems and people in a changing world. Island Press, London
Wallerstein IM (2004) World systems analysis: an introduction. Duke University Press, Durham
Webster CS (2005) The nuclear power industry as an alternative analogy for safety in anaesthesia and a novel approach for the conceptualisation of safety goals. Anaesthesia 60:1115–1122

Wigley TML, Ingram MJ, Farmer G (eds) (1981) Climate and history. Studies in past climates and their impacts on man, Cambridge University Press, Cambridge

Wise RM, Fazey I, Smith MS, Park SE, Eakin HC, Van Garderen ERMA, Campbell B (2014) Reconceptualising adaptation to climate change as part of pathways of change and response. Glob Environ Chang 28:325–336

WCED (1987) Our common future. World Commission on Environment and Development. New York and Oxford, Oxford UP

Yudkowsky E (2008) Cognitive biases potentially affecting judgement of global risks. In: Bostrom N, Milan C (eds) Global catastrophic risks, pp 91–120. Oxford, UP

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